Algorithms and the 'Art' of Medicine

Over the past 30 years, there have been increasing attempts to transform the "art" of medical decision-making into a "science," to supplement a spontaneous, informal, and implicit set of judgments with the conclusions of a predetermined, formal, and explicit scheme of logic. The driving force behind this effort has been the perception that clinicians make medical decisions in an idiosyncratic manner, sometimes compromising the quality of care or wasting medical resources. The continuing resistance to this effort has been based on a fear that medical care would become regimented, uninspired, and mediocre if all of the "art" were removed from medical decision-making.

The growing experience with clinical algorithms demonstrates that the hypothetical benefits of such efforts are likely to outweigh the hypothetical risks. Also called "protocols," clinical algorithms are an explicit description of appropriate steps to be taken in the care of a patient with a particular problem. An algorithm indicates appropriate history, physical examination, and laboratory data to be obtained, and makes precise recommendations for diagnosis and/or treatment, based on the data which have been obtained. Algorithms include branching logic which allows recommendations to be "individualized" according to the patient's age, sex, past illness, current medications, and current clinical findings.

While algorithms were familiar to the small group of workers in the field of medical decision theory, they did not achieve widespread visibility until they were introduced as tools to educate new health practitioners (NHPs)—particularly nurse practitioners and physician assistants. This initial work was spearheaded by Sox and Tompkins,[1] Vickery and others in the Army's Project AMOS,[2] and by our group.[3]

Over the past decade, the use of algorithms has expanded. Ten years ago, "algorithm" was an unfamiliar term and concept to most clinicians. Indeed, even as the concept became familiar, the term seemed to remain alien; our group received many communications from people asking to see copies of our "logarithms." (The differences between algorithms and logarithms are, of course, exponentially large.)

Algorithms have been developed for the care of patients with acute minor illnesses,[1,2,4-13] chronic disease,[3,14] acute medical emergencies,[15] and minor surgical problems,[16] as well as to aid pediatric telephone triage,[17] and to help detect disease in the worksite.[18] Algorithms have also been used by pharmacists to help physicians follow patients returning for prescription refills[19] to train radiologic technologists to help interpret x-rays,[20-22] and to guide health auxiliaries delivering patient care without immediate physician support in the developing nations.[23,24]

Prospective, controlled trials of the use of algorithms by NHPs have investigated the quality and cost of care. All of these studies have been conducted in institutional group practices with salaried physicians, and not in the more typical fee-for-service solo or small group practice setting. The reported studies have demonstrated that the quality of care (both process and outcome) and patient satisfaction were never worse and often significantly better than when patients saw physicians only, in the traditional mode.[3,7,11] Finally, the cost of care in an NHP-algorithm system has been demonstrably lower than in a "physician-only" system; in addition to significant savings in the cost of manpower, significant reductions in the use of diagnostic tests and medications often have been achieved.[7,8,13,25] Elsewhere in this issue of the Journal, Christensen-Szalanski and his colleagues add to the evidence indicating the cost-containment potential of algorithms.[26]

Several concerns about the use of algorithms have not been borne out by experience. Many people seemed to imagine that NHPs would proceed in a mechanical lock-step through the algorithm, insensitive to a patient's hidden agenda or apprehensions, blind to clues about disease not "suspected" by the algorithm, and incapable of providing reassurance and explanation. In fact, the use of algorithms has never been such an exercise in robotics, as attested to by the many studies which have demonstrated excellent patient satisfaction and outcome. Algorithm users rapidly learn the algorithm content and logic, and interview patients according to the natural flow of conversation. Furthermore, NHP's using algorithms in practice are encouraged to deviate from the recommendations of the algorithms, when they have good reason for doing so. The report by Christensen-Szalanski in this issue documents that NHP's indeed do not always follow the recommendations of an algorithm. Whether this is good or bad can only be determined by a study of patient outcome, in the individual case. Our own anecdotal experience has been that most deviations have no impact on outcome, a few introduce unnecessary risks, and a few reflect sound judgment which increases the probability of benefit.

Many people expressed the concern that NHP students would be trained to memorize the algorithms but not educated to understand the reasoning and principles upon which the algorithms were based. However, every group which has used algorithms in the education of NHP's has made algorithms only one part of an otherwise traditional curriculum which stressed the fundamentals.

The early algorithms, reflecting a conservatism appropriate in the first years of experience with NHP's, often required a lengthy examination and an extensive use of laboratory tests. If this had not changed, it would have justified the concern that the use of algorithms would lead to unacceptably time-consuming and expensive care. However, the algorithm developers carefully studied the results of their experience with thousands of patient encounters. Clinical or laboratory data which had a demonstrably small yield, regardless of how venerable, were eliminated. Wood's group has described this process most elegantly.[27] The algorithm developers also have changed the algorithms to conform to new knowledge and technology, and have thus far avoided the danger of conferring upon any algorithm a premature sanctification.

Although algorithms are referred to during the encounter with a patient only in a minority of cases, they have gained widespread acceptance as a technique for describing

the practice standards of NHPs. Several states have required by law that algorithms (or "protocols") be developed by each NHP and the physician copractitioner. Textbooks incorporating algorithms have been quite popular.[28–30]

We have been impressed by the increasing popularity of algorithms as educational tools for *patients* and *physicians*. Recently, several books have been published which have the goal of educating patients in the initial care and triage of their own problems, using algorithms which the patient can follow.[31–33] Collectively, the books have sold several million copies.

The growing interest of physicians in algorithms as educational tools is indicated by the increasing frequency with which algorithmic flow charts are seen in medical textbooks and journals. The *Journal of the American Medical Association*, the *Journal of Infectious Diseases*, and *Patient Care* have run or are running long series which employ algorithms. A collection of algorithms to aid surgical decision-making[34] has become one of the most popular new surgical textbooks in several years. Greenfield and his colleagues have used algorithmic "criteria maps" successfully as quality assurance tools for physicians,[35] giving greatly-needed flexibility to the standards.

In a few cases, algorithms have been used—as either printed or computer-generated reminders—by physicians during patient care. In these cases, the process of care has improved. For example, Grimm[8] demonstrated that physicians used antibiotics more appropriately when using algorithms, and McDonald[36] showed that a variety of diagnostic tests and treatments were used more appropriately by physicians who received computer-reminders. Wirtschafter[37] developed a system by which community physicians could deliver cancer chemotherapy to patients in their own home towns, with the aid of algorithms developed and monitored by specialists at a regional cancer center.

It is likely that algorithms will continue to grow in popularity as techniques for education and standard-setting. At the same time, it is likely that most clinicians will not use algorithms routinely during the process of caring for each individual patient, in the way that some of us have suggested; many clinicians find the routine use of algorithms to be demeaning, particularly if they have not been the principal authors of the algorithms. A clinician said to me once, "I am being regimented if you give algorithms to me, but I am being systematic if I develop algorithms for myself."

While algorithms may continue to play a role in medical decision-making, it is unlikely that they will find any role in the two other critically important aspects of caring for the patient: listening to the patient for what is said, how it is said, and what is not said; and explaining, providing reassurance, and showing that one cares. Algorithms are no substitute for experience, sensitivity, or compassion.

Will algorithms stifle creative thinking and encourage mediocrity? The perils of mindless adherence to any standards—algorithmic or otherwise—are certainly real. Standards need not become dogma, however. In our judgment, a great virtue of algorithms is that, by making an explicit recommendation, they invite challenge and help focus the debate. Most of all, they serve as a device for integrating information. This seems especially important in the 1980s. With the explosion of information about pathophysiology, and the proliferation of diagnostic and therapeutic technologies, it has become imperative for the clinician to resist "future shock," to *organize* this information around the question he or she faces every day: what should one *do* in caring for a patient with a particular problem? What is a logical approach to the diagnostic workup, and to the plan of therapy?

In our view, algorithms can help us to articulate how we make decisions, to clarify our knowledge and to recognize our ignorance. They can help us to demystify the practice of medicine, and to demonstrate that much of what we call the "art" of medicine is really a scientific process, a science which is waiting to be articulated.

ANTHONY L. KOMAROFF, MD

Dr. Komaroff is with the Division of General Medicine and Primary Care, Department of Medicine, Brigham and Women's Hospital, Harvard Medical School, Boston, MA 02115.

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Refugees, Immigrants, and the Public Health

Several papers in recent issues of the Journal,[1,2] including the one by Skeels, *et al*,[3] in the current issue, bear witness to an upsurge of interest in the medical problems of recent immigrants and refugees. The Index Medicus for 1980, under the heading, emigration and immigration, lists 33 papers published in American journals on health problems of immigrants to the United States and another 18 such papers under the heading, refugees. In 1970 there was no heading "refugees", and only four comparable papers were listed under the heading emigration and immigration. The upsurge is not surprising. In 1978 (the most recent year for which figures are published) 601,442 immigrants were admitted to the United States, the largest number since 1921.[4]

Immigration has played a pivotal role in American history, but its role in the history of public health is less well recognized. One of the earliest actions of the Congress in 1796 provided for federal "cooperation" with states and localities in enforcing state and local quarantine relating to ships.[5] Although a few legislators argued as early as 1796 that the federal government should be given greater powers, the Congress avoided stepping on the toes of States for the next 82 years and even then did so very lightly: The Quarantine Act of 1878 specified that any regulations of the Surgeon General of the Marine Hospital Service to whom the federal power of quarantine was delegated "shall not conflict with or impair any sanitary or quarantine laws or regulations of any state or municipal authorities now existing or which may hereafter be enacted".[5] In spite of these limitations, the 1878 Act represented a significant broadening of the authority of the United States Public Health Service, then known as the Marine Hospital Service. The law included a charge "to investigate the origin and causes of epidemic disease and cholera," thus initiating a course of action whose ultimate product was the present Naitonal Institutes of Health.[6]

Pressures to enact the 1878 law came from many sources, all related to the rising tide of immigration.[7] The fear of imported epidemics was one of these sources, and a growing consensus favorable to the germ theory of disease kindled hopes that contagion could be easily contained by quarantine. In the forefront of such believers were members of the newly formed (1872) American Public Health Association (APHA).

The quarantine responsibilities of the Marine Hospital Service lasted but a short time, being transferred in 1879 to the ill-fated National Board of Health.[5] The 1879 law was a virtual brain child of the APHA and Association officers were prominent as members of the Board. Its passage was greatly accelerated by a severe epidemic of yellow fever in 1878, however. According to the Board's Chairman, James L. Cabell, sixth president of the APHA, the law was intended to carry a provision for funding the first state grants-in-aid program for public health work, a block grant, "to aid in the work of State Boards of Health, and of State